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BIT	7	6	5	4	3	2	1	0
OCTET 0	1	1	1	0	0	0	0	0
OCTET 1	SLOT LIST SEQUENCE NUMBER				ACCESS CONTROL		LIST TYPE	
OCTET 2	PHYSICAL CHANNEL NUMBER							
OCTET 3	PHYSICAL CHANNEL NUMBER							
OCTET 4	PHYSICAL CHANNEL NUMBER							

(57) Abstract

In a system involving communication in predetermined time slots within fixed length time frames, data of which carrier radio frequencies are available to a transmitting/receiving unit is sent to that unit so as to control its communications.

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Method and Apparatus for Selection of a Radio Channel

This invention relates to digital data and control message transmission in predetermined time slots within fixed length time frames.

The invention is defined in the claims, to which reference should now be made.

The present invention relates to a method of transmitting control messages in predetermined time slots within fixed length time frames from a first transmitting and receiving unit to a second transmitting and receiving unit for controlling the second unit, the control message comprising data of the availability of carrier radio frequencies to the second unit for communication with first unit. Preferably the availability data indicates which carrier radio frequencies are preferred for use, which are less preferred for use, and which are not for use. It is preferred that the availability data is updated and dependent on whether communication on each selected carrier radio frequency is successful, and the availability data is retransmitted periodically.

The invention also relates to a corresponding method of transmitting digital data signals, a transmitter, and communication means.

A preferred embodiment of the invention will now be described, by way of example, and with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram illustrating the system including a base station (BTE - Base Terminating Equipment) and subscriber unit (NTE - Network Terminating Equipment);

Figure 2 is a diagram illustrating frame structure and timing for a duplex link;

Figure 3 is a diagram representing a slot-list message from a base station.

The Basic System

As shown in Figure 1, the preferred system is part of a telephone system in which the local wired loop from exchange to subscriber has been replaced by a full duplex radio link between a fixed base station and fixed subscriber. The preferred system includes the duplex radio link, and transmitters and receivers for implementing the necessary protocol. There are similarities between the preferred system and digital cellular mobile telephone systems such as GSM which are known in the art. This system uses a protocol based on a layered model, in particular one having the following layers: PHY (Physical), MAC (Medium Access Control), DLC (Data Link Control), NWK (Network). One difference compared with GSM is that, in the preferred system, subscriber units are at fixed locations and there is no need for hand-off arrangements or other features relating to mobility. This means, for example, in the preferred system, directional antennae and mains electricity can be used.

Each base station in the preferred system provides six duplex radio links at twelve frequencies chosen from the overall frequency allocation, so as to minimise interference

between base stations nearby. The frame structure and timing for the duplex link is illustrated in Figure 2. Each duplex radio link comprises an up-link from a subscriber unit to a base station and, at a fixed frequency offset, a down-link from the base station to the subscriber unit. The down-links are TDM, and the up-links are TDMA. Modulation for all links is $n/4$ - DQPSK, and the basic frame structure for all links is ten slots per frame of 2560 bits, i.e. 256 bits per slot. The bit rate is 512kbps. Down-links are continuously transmitted and incorporate a broadcast channel for essential system information. When there is no useful information to be transmitted, the downlink transmission continues to use the basic frame and slot structure and contain a suitable fill pattern and essential broadcast channel.

For both up-link and down-link transmissions, there are two types of slot: normal slots, which are used after call set-up, and pilot slots which are used during call set-up.

Each down-link normal slot comprises 24 bits of synchronisation information followed by 24 bits designated S-field which includes an 8 bit header, followed by 160 bits designated D-field. This is followed by 24 bits of Forward Error Correction, and an 8 bit tail, followed by 12 bits of broadcast channel. The broadcast channel consists of segments in each of the slots within a frame which together form the down-link common signalling channel which is transmitted by the base station, and contains control messages containing link information such as slot lists, multi-frame and super-frame information and other information, connectionless messages and information basic to the operation of the system.

During call set-up, each down-link slot contains frequency correction data and/or a training sequence for receiver initialisation with only a short S- field and no D- field information.

Up-link slots basically contain two different types of data packet. The first type of packet, called a pilot packet, is used before a connection is set up, for example, for an ALOHA call request and to allow adaptive time alignment. The other type of data packet, called a normal packet, is used when a call has been established and is a larger data packet, due to the use of adaptive time alignment.

Each up-link normal packet contains a data packet of 244 bits which is preceded and followed by a ramp of 4 bits duration. The ramps and the remaining bits left of the 256 bit slot provide a guard gap against interference from neighbouring slots due to timing errors. Each subscriber unit adjusts the timing of its slot transmissions to compensate for the time it takes signals to reach the base station. Each up-link data packet comprises 24 bits of synchronisation data followed by an S-field and D-field of the same number of bits as in each down-link normal slot.

Each up-link pilot slot contains a pilot data packet which is 92 bits long preceded and followed by 4 bit ramp defining an extended guard gap of 60 bits. This larger guard gap is necessary because there is no timing information available, and without it, propagation delays cause neighbouring slots to interfere. The pilot packet comprises 64 bits of sync followed by 104 bits of S-field which starts with an 8 bit header and finishes with a 16 bit Cyclic Redundancy Check 2 reserved bits, 14 forward error

correction FEC bits, and 8 tail bits. There is no D-field.

The S-fields in the above mentioned data packets can be used for two types of signalling. The first type is MAC signalling (MS) and is used for signalling between the MAC layer of the base station and the MAC layer of a subscriber unit in which timing is important. The second type is called associated signalling, which can be slow or fast, and is used for signalling between the base station and the subscriber units in the DLC or NWK layers.

Call requests are made in random access Aloha slots as described in more detail below.

Provision is made in the preferred system for subscriber unit authorisation using a challenge response protocol. General encryption is provided by combining the speech or data with a non-predictable sequence of cipher bits produced by a key stream generator which is synchronised to the transmitted super-frame number.

In addition, the transmitted signal is scrambled to remove dc components.

Contention Protocol

A slotted Aloha protocol is used by subscriber units to send call set-up requests and short information messages (Datagrams) to the base station. These requests and messages are sent in a pilot packet in one of a list of slots, known as Aloha slots, that have been designated as available for this purpose in a Slot-List broadcast by the base station. A typical slot-list broadcast is illustrated in Figure 3. A slot-list is valid for a

multiframe, which consists of sixteen consecutive frames numbered 0 - 15, and is broadcast in one multiframe to be applicable to the following multiframe. The number of Aloha slots in a Slot-List may vary from 0 to 48, and thus the message containing this information is of variable length and may need to be segmented into several slot-list messages for transmission in the broadcast channel. Each slot-list message may designate up to three Aloha slots, as shown in the Figure 3. A minimum number of slot-list messages are used, and these are each assigned a sequence number and are sent in ascending order, and are re-transmitted in the same order following complete transmission within the same multiframe. Typically, however, a single slot-list message will be sufficient to transmit the complete Slot-List.

The broadcast channel itself comprises a predetermined portion of each slot in every frame of the multiframe, and is used to broadcast various messages besides slot-list messages. Furthermore, different priorities are allocated to these different types of messages. Thus in frames 0 to 7 of a multiframe, slot-list messages have the lowest priority, and may not be transmitted because of the volume of other messages. However, slot-list messages are given a high priority in frames 8, 9, 12 and 13 so that transmission of at least a part, and most probably all, of the Slot-List is guaranteed.

The information in the Slot-List is encoded for reduced bandwidth, and has to be decided by reference to a Carrier-List which includes details of bearer frequencies. This Carrier-List is also transmitted in the broadcast channel in frame 15 of the multiframe preceding that in which the Slot-List is transmitted.

The base station sends information specific to each subscriber unit of which RF carrier frequencies are:

- (i) preferred (the so-called 'white' channels)
- (ii) to be used if a preferred rf frequency is not available (the so-called 'grey' channels)
- (iii) not to be used (the so-called 'black' channels).

Each subscriber unit stores this information.

RF frequencies are categorised as 'black' if, for example, their use by one sector is likely to cause interference with transmissions from subscriber units in neighbouring sectors such that interference from other transmissions is avoided. RF frequencies are categorised as 'grey' where they provide poor quality but acceptable propagation.

The base station controls which slots are to be included in the Slot-List taking into account the extent to which the network is currently loaded. The Aloha slots can be distributed evenly across the available radio frequency channels, although they need not be.

There may be separate Slot-Lists for call set-up requests and datagrams or a single Slot-List for both, and therefore a List-Type parameter is incorporated in each slot-list message to indicate the type of messages to be sent in the listed slots.

An Access Control Indicator is incorporated in each slot-list message and is the same

for all segments of a segmented slot-list message. The Access Control Indicator is used to restrict access to emergency calls or priority users at various levels of network loading. Customers can subscribe to either of two priority services or a normal service. When the network loading is high, normal users are denied access except for emergency calls. When the network loading is virtually at capacity, all types of user are denied service except for emergency call attempts.

The Access Control Indicator may take an integer value between 1 and 4. The services are available for each of these values as follows:

<u>Level</u>	<u>Priority A User</u>	<u>Priority B User</u>	<u>Normal User</u>
4	Emergency calls only	Emergency calls only	Emergency calls only
3	Any call	Emergency calls only	Emergency calls only
2	Any call	Any call	Emergency calls only
1	Any call	Any call	Any call

Each subscriber unit maintains a Classified Carrier-List corresponding to the information received from the base station indicating radio frequency channels that are preferred ("white"), slots that are only to be used due to the poor quality they provide if no preferred slot is available ("grey"), and slots which are not to be used ("black").

Rules for Contention by Subscriber Units

A subscriber unit receives Aloha slot-list messages on the broadcast channel, starting

with the first slot-list message in a multi frame, and compiles a valid Slot-List for the following multiframe which takes account of any 'black' or 'grey' channels in the Classified Carrier-List or which are not of the appropriate type (call set-up requests or Datagrams) as indicated by the List-Type. It can be considered that the Slot-List is added with the Classified Carrier-List data of RF frequency channels to provide a valid Slot-List of slot/RF frequency/List-Type/Access Control Indicator settings suitable for use. Of course, RF frequencies categorised 'white' are preferred to those categorised 'grey'.

Following reception of the final slot-list message in a sequence, the subscriber unit selects one of the Aloha slot/RF frequency settings at random from the entries of appropriate List-Type in the valid Slot-List. The subscriber unit then transmits at the selected frequency and in the selected slot, a message which is either a datagram or a call set-up request. The datagram or call set-up request is sent to the base station in the selected slot at the next possible opportunity according to the setting of an extended Aloha parameter e broadcast by the base station.

If the extended Aloha parameter e is set to 1, then the message to be sent is transmitted once in the next frame. If the parameter e is set to 2, then the message is transmitted in the next frame in the set (0,2,4,6,8,10,12,14), and is repeated in the frame immediately following that in which it was first transmitted, for example, if the current frame is 5, the message shall be transmitted in frames 6 and 7. If the parameter e is set to 4, then the message is transmitted in the next frame in the set (0,4,8,12), and the message is repeated in the three consecutive frames following that in which it was first

transmitted, for example, if the current frame is 5, the message shall be transmitted in frames 8,9,10,11.

If a complete Slot-List is not transmitted in a multiframe, the subscriber unit can still make use of the Aloha slot information that it has received in order to send a message in these slots.

Following transmission of a message, the subscriber unit then listens to the broadcast channel for 16-e frames and compiles a valid Slot-List for the following multiframe, and selects one of the slots x at random in case a re-transmission is required. However, if having sent a call set-up request, the subscriber unit receives an acknowledgement message from the base station in the broadcast channel, then the subscriber unit takes no further action to re-transmit the call set-up request. However, if an acknowledgement message is not received, the subscriber unit acts to re-transmit the call set-up request provided a maximum permissible number of re-transmissions has not already taken place. A re-transmission counter is incremented each time the call set-up request is transmitted so as to monitor the number of re-transmissions.

Re-transmission of a call set-up request follows the same procedure as the initial transmission in determining the slot and frame(s) used, except that there is a further rule that if the number of valid Aloha slots is less than four, then re-transmission may be delayed beyond the next frame that would otherwise be used, a random number y being generated between 1 and 4 to determine whether the first, second, third or fourth available frame is used. For example, if the extended Aloha parameter $e = 4$, $y = 2$ and

the current frame = 3, the call set-up request shall be transmitted in frames 8,9,10,11.

Aloha Slot List Management

Base stations send slot list messages to subscriber units and manage slot lists dependent on the Carrier-lists they have stored for each associated subscriber unit. Where certain RF frequencies are designated as not to be used ('black'), the base station manages slot list messages so as to ensure that each subscriber unit always has an RF frequency available for use. In particular, at periods of high loading where selected classes of subscriber units are restricted from making calls, the base station operates to ensure that an Aloha slot will be available to a subscriber unit within a predetermined time period.

Network Loading

At times of high loading, access to the network may need to be restricted. If the number of Aloha slots reduces sufficiently, the network will restrict access to emergency calls only. In an extreme situation, access for new call attempts may be denied completely by disabling the Slot-Lists. The network has the following means of controlling access:

- reducing the number of Aloha slots available
- using the Access Control Parameter
- restricting access to datagrams or call set-up requests only
- restricting access to selected types of calls
- restricting the number of time slots per frame assigned to a call.

In periods when the network is highly loaded, for example when there are many Public

Telephone Switched Network (PSTN) calls, access to the network can be restricted. PSTN calls are the normal 32kbps speech calls to or from a subscriber, or PSTN fax/data calls which use 2 time slots per fixed length time frame, ie. requiring 64kbps of bandwidth.

The level of usage in the network is monitored and calls are progressively restricted, as described below, as each of a series of usage thresholds is reached:

1. With increasing loading of the network, firstly test calls, which do not earn revenue, are prevented. Optionally, existing test calls can be immediately terminated.
2. At a higher threshold, system control calls requiring assignment of at least one time slot per frames are prevented.
3. At a still higher threshold, assignment of a second time slot per frame to calls usually sent with more than one time slot per frame is prevented. Thus PSTN fax/data calls are sent more slowly than usual.
4. At the next highest group of thresholds, only selected call types can be made by selected groups of subscribers. In particular non-emergency PSTN calls are prevented for various types of subscriber dependent on the Access Control Parameter. Specifically subscribers can be normal users, priority B users or priority A users as described above, each type of user having a different access priority. Subscribers sharing a subscriber unit can have different priorities.

At the highest threshold, the last two channels are reserved for emergency calls only. Thus where there are say 60 channels (time slot/carrier frequency combinations), at a time of high loading the call set-up request for the 59th PSTN call at that time would be refused unless it is an emergency call. Of course, the number of reserved channels at the highest threshold can be other than two.

Updating the Classified Carrier List dependent on Call Success

The base station monitors, over time, the success of Public Switched Telephone Network (PSTN) calls and test calls on each RF frequency to each subscriber unit with which it communicates by radio. Where necessary an RF frequency is recategorised. For example, an RF frequency categorised as 'white' can be automatically reclassified as 'grey' should the frequency be unavailable for successful call transmission for more than a predetermined percentage of time. Conversely, 'grey' frequencies which are monitored as becoming sufficiently reliable are re-categorised as 'white'.

RF frequencies which are sufficiently unreliable, or cause interference are re-categorised as 'black'. The updated Classified Carrier list for each subscriber unit is updated periodically.

CLAIMS

1. A method of transmitting control messages in predetermined time slots within fixed length time frames from a first transmitting and receiving unit to a second transmitting and receiving unit for controlling the second unit, control messages comprising data of the availability of carrier radio frequencies to the second unit for communication with the first unit.
2. A method of transmitting control messages according to claim 1, in which the availability data indicates which carrier radio frequencies are preferred for use, which are less preferred for use, and which are not for use.
3. A method of transmitting control messages according to claim 1 or claim 2, in which the availability data is updated dependent on whether communication on each selected carrier radio frequency is successful, and the availability data is retransmitted from time to time.
4. A method of transmitting control messages according to any of claims 1 to 3, from a first unit to a plurality of second units in which further control messages are transmitted comprising information indicating time slots and carrier radio frequencies selectable for set-up requests by any of said plurality of second units.
5. A method of transmitting control messages according to claim 4, in which a second unit selects at random for a call set-up request from the time slots indicated as available.

6. A method of transmitting control messages according to any preceding claim, in which the first unit manages the carrier radio frequencies to ensure that the second unit has a radio carrier frequency available within a predetermined time for a call set-up request.

7. A method of transmitting control messages according to any of claims 1 to 6, in which transmission is by radio.

8. A method of transmitting digital data messages in predetermined time slots within fixed length time frames between a first transmitting and receiving unit and a second transmitting and receiving unit, including sending a control message from the first unit to the second unit, the control message comprising data of the availability of carrier radio frequencies for use by the second unit.

9. A transmitter comprising means operative to transmit control messages in predetermined time slots within fixed length time frames, including means to incorporate within the control messages data of the availability of carrier radio frequencies for communication.

10. Communication means comprising a base station and plurality of subscriber units, the base station communicating with each subscriber unit by sending and receiving messages in predetermined time slots within fixed length time frames, in which each subscriber unit receives control messages from the base station comprising data of the availability of carrier radio frequencies for communicating with said each subscriber

unit.

11. Communication means according to claim 11, in which the subscriber units are at fixed locations.

12. Communication means according to claim 10 or claim 11, in which said each subscriber unit compares its received carrier radio frequency availability data with information of time slots and carrier radio frequencies available to said plurality of subscriber units, to determine the sub-set of time slot and carrier radio frequency settings available for transmission of its set-up requests.

13. Communications means according to claim 12, in which said information of time slots and carrier radio frequencies available to said plurality of subscriber unit is received in control messages sent by the base station.

14. Communication means according to any of claims 10 to 13, in which the availability data is stored in memory.

FIG. 1

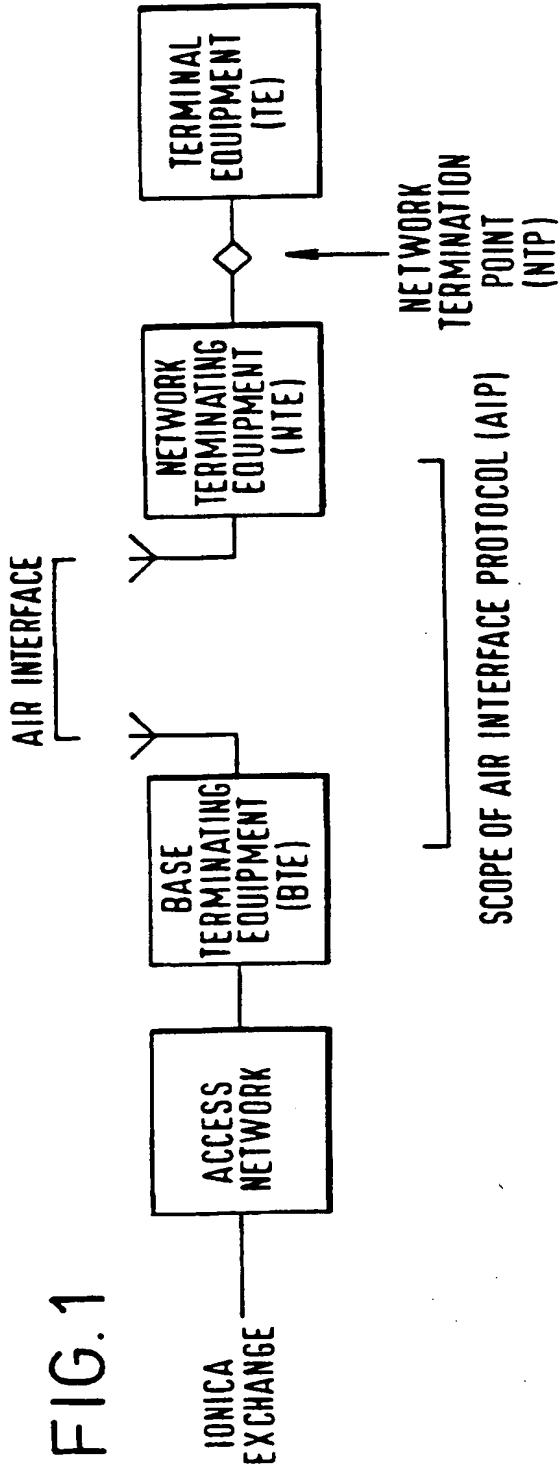
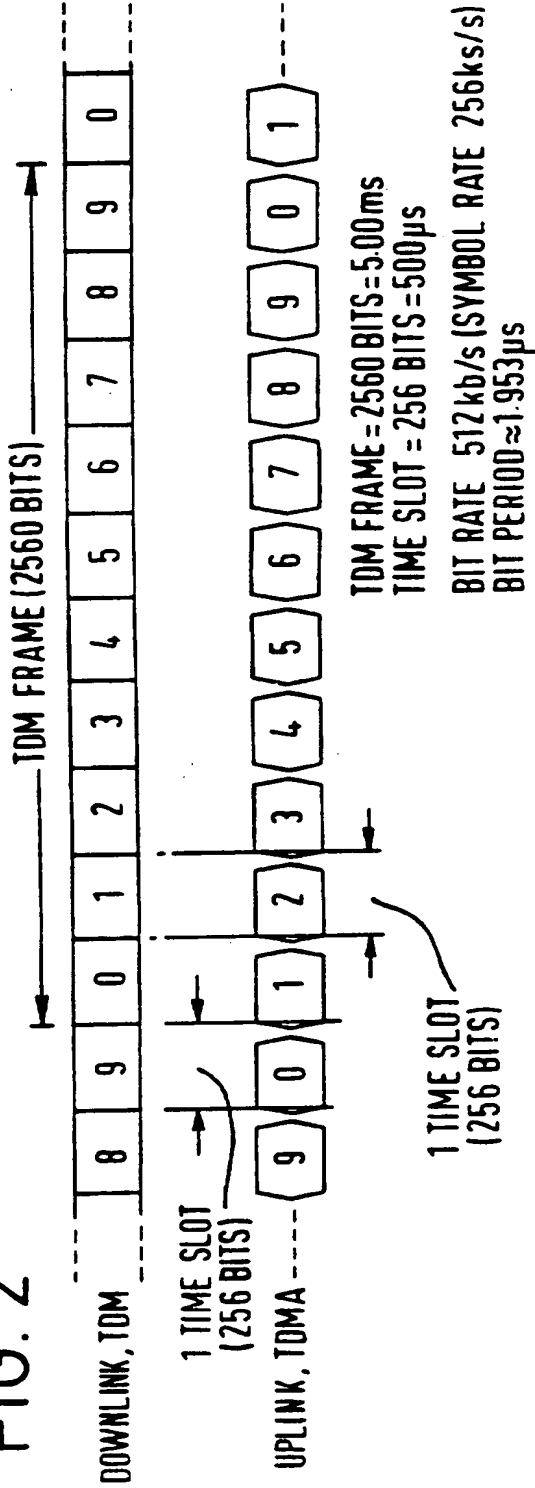


FIG. 2



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 419 244 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION) 27 March 1991 see page 4, line 41 - page 5, line 54 ---	1, 3, 4, 7-10, 12-14
X,P A,P	GB,A,2 277 849 (SPECTRONICS MICRO SYSTEMS LIMITED) 9 November 1994 see page 6, line 7 - line 24 see page 7, line 28 - line 31 -----	1, 7-10, 12, 13 2, 3

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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